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# ON THE NATURE OF RADIONOISE EMISSION FROM THE SURFACE OF VENUS


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## SUMMARY

The increased level of radionoise emission of Venus (600 – 700° K) may be explained by "silent" or "glowing" discharges in the upper atmosphere which induce radionoise accretion by 200 — 300° K above the true thermal radio emission.

The main factor determining the development of a "silent" or "glowing" atmospheric discharge instead of phenomena of thunderstorm character inherent to Earth, may be the extremely slow rotation of the planet, with the connected little turbulent but quite intense atmosphere circulation encompassing nearly its entire surface.

The calculations of the efficiency of Sun's thermal energy transformation into radionoise energy, through intermediate stages, into the atmosphere circulation energy and that of electric currents, demonstrate the reality of the proposed "gas-discharge" model of radionoises.

* * *

Radioastronomical observations of Venus in wavelengths of 10, 3, 0.8 and 0.4 cm [1 – 6] have shown that the radionoise emission, originating from the planet's disk, corresponds to the thermal radio emission of a blackbody heated to a temperature ~ 700° K (in the 3 and 10 cm wavelengths) and to 400 - 500° K (in the 0,8 and 0.4 cm bands). Various hypotheses were brought forward to explain such a high level of radio emission:

— the radionoise emission originates from the planet's surface, heated at the expense of the "greenhouse" effect in the atmosphere [7];

— the emission is induced by the motion of charged particles in the heated and quite rarefied layers of Venus' ionosphere [7, 8].

* O PRIRODE RADIOSHUMOVOGO IZIUCHENIYA POVERKHNOSTI VENERY.

One of the methods for choosing between these hypotheses would be the experiment on the investigation of intensity distribution of radionoises along the planet's disk. It was shown in [9], for example, that the "darkening toward the limb" would correspond to the emission of planet's heated surface, whereas the "brightening toward the limb" would be ascribed to an ionospheric origin of radionoises.

An attempt of investigating the radionoise distribution along the disk of the planet was carried out during Mariner-2 flight to Venus, equipped on that occasion with a radiometric apparatus.

Figures 1 and 2 illustrate the data on the work of Mariner-2 radiometer published in [9, 10]: the registration of telemetric signals and the scanning scheme along the planet's disk. As may be seen from Fig. 2, there were three passages along the disk in all : the median passage coincided with the planet's terminator, and the two marginal ones passed respectively by the daytime and nighttime sides. As is well known, the Mariner-2 flight passed at an unexpectedly great distance from the planet, so that the obtained details of radiobrightness distribution were below the anticipated, being characterized by a number of independent readings of the order of 5 to 8 for a single passage.

Therefore, Mariner-2 failed to provide a detailed picture of radiobrightness distribution along the disk. The data obtained may be treated as both, the regular "brightening toward the center , characteristic of the "greenhouse" hypothesis, and as a certain other distribution, characteristic for example, of the brightness increase in the terminator region for the "gas-discharge" model considered below.

The solution of the problem of the nature of Venus' radionoise emission is made more complex by the fact that neither the "greenhouse", nor the "ionospheric" hypotheses have found to-date a full theoretical support. The main difficulty in explaining the "greenhouse" model consists, as is shown by Jastrow and Rasool [11], in that we have to assume an extremely high degree of opacity of Venus' atmosphere in infrared rays in order to explain the surface heating to $600^{\circ}$ K at the expense of "greenhouse" effect. These authors have shown that when accounting for the radiation heat transfer, one should admit an optical thickness of the atmosphere equal to 60, that is, a nontransparence characterized by emission's transmission factor through the atmosphere equal to $e^{-60} = 10^{-26}$. When explaining the "ionospheric" hypothesis, one should admit that the electron concentration in the ionosphere of Venus exceeds that in the terrestrial atmosphere by about 1000 times. The causes of such a high electron concentration are unexplained, which constitutes the principal difficulty in the theoretical foundation of the ionosphere hypothesis.

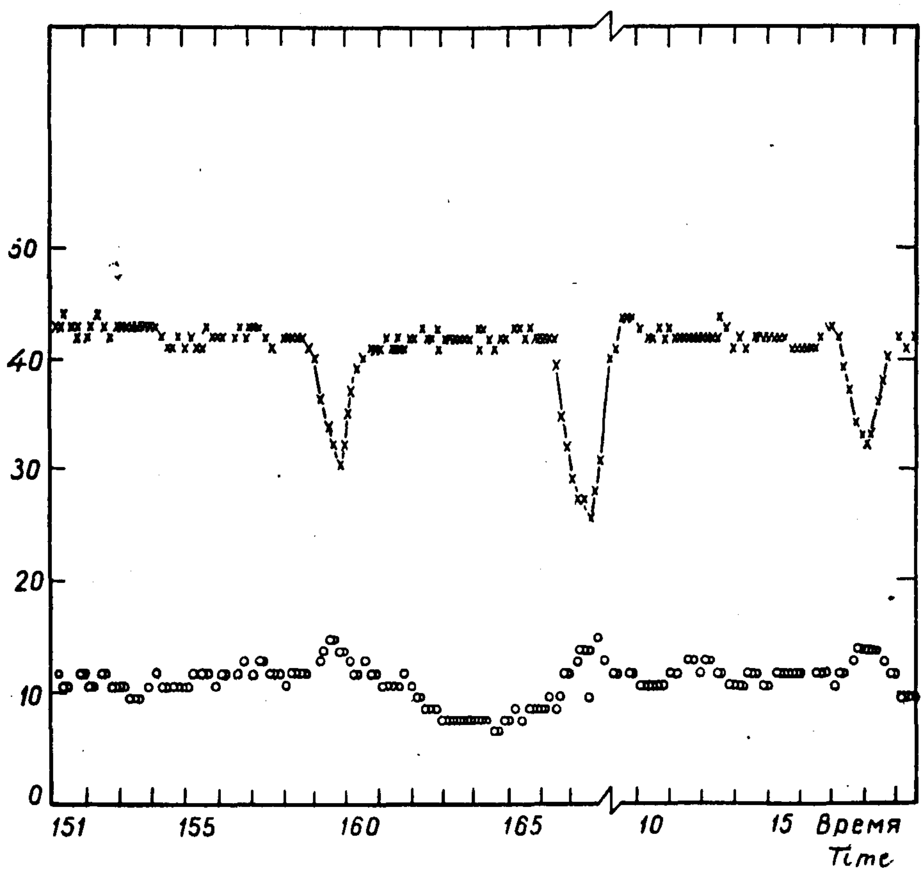


Fig. 1. - Registration of telemetric signals from the radiometer of Mariner-2

In connection with the above difficulties it appears to be interesting that the so-called "silent" and "glowing" electrical discharges in a rarefied gas may induce quite an intense radionoise emission at substantially weaker radiation in the infrared and optical bands.

Thus, for example, fluorescent tubes, filled by an inert gas at pressure of the order of 1 — 10 mm Hg, usually induce radionoise emission in the band through wavelengths of the order of 3 cm, corresponding to temperatures of the order of 10 000 — 40 000° K. In shorter wavelengths (microwave, infrared and optical bands) the emission flux is substantially less intense and corresponds to temperatures of the order of 300 — 400° K (as an average for the band, omitting the narrow bands of the line spectrum of the discharge glow). The dependence on wavelemgth of Venus' proper emission intensity has the same character: the high temperatures in the centimeter band (600 - 700° K) match the lower temperatures in the microwaves (400 — 500° K) and with a temperature of the order 235 — 240° K in the infrared. This why we may assume that silent and glowing electric discharges take place in the rarefied layers of Venus' atmosphere in a continuous manner; they encompass sufficiently large regions of the planet, creating radionoises, which add up to the purely thermal radio emission.

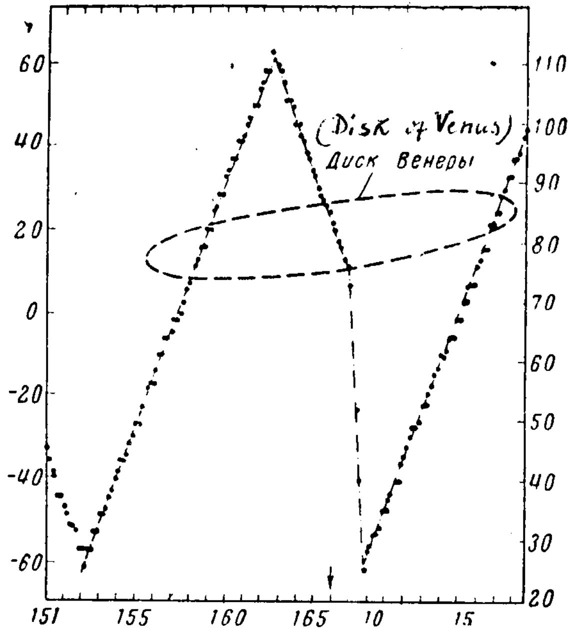


Fig. 2. - Scanning scheme by the planet's disk.

The principal factor determining the development of silent and glowing discharges in the atmosphere of Venus instead of the thunderstorm phenomena characteristic of the Earth's atmosphere may be the extremely slow rotation of the planet, established by radar location. Contrary to the Earth, where the movement of air between the heated and cold regions of the planet is strongly distorted on account of Coriolis acceleration as well as because of frequent changes of heating and cooling periods of thermally nonuniform regions, such as the oceans, and continents, a unique movement of air masses of the "breeze" type, that is, a regular, little turbulent flow between the dark and lit sides of the planet, must prevail on a slowly rotating planet. The atmospheric flow of such a type ("global breeze") is quite favorable to intense "silent" and "glowing" electric discharges in the upper layers of the atmosphere. Indeed, at such a circulation there must take place an intense gas electrification at the expense of friction on the hard surface and a continuous accumulation of charges of various denominations on either side.

Inasmuch as the mobility of electrons and ions rises with height, the atmosphere has its highest conductance in the upper rarefied layers. Consequently, if the charges of various denominations are scattered sufficiently far, to a distance exceeding by several times the height at which the conductance is maximum, the electric current, balancing the constant accumulation of charges, will pass through the upper layers of the atmosphere creating within it effects of "silent" and/or "glowing" discharge (Fig. 3).

Thus, according to the assumption just made, the thermal energy of the Sun transforms into radionoises in two ways :

— in the form of the standard radionoise emission of a heated body;

— in the form of radionoises of a "glowing discharge.

At the same time the thermal energy of the Sun transforms into energy of atmospheric flows, then into energy of atmospheric electric currents, and finally into the radionoise emission of the gas discharge.

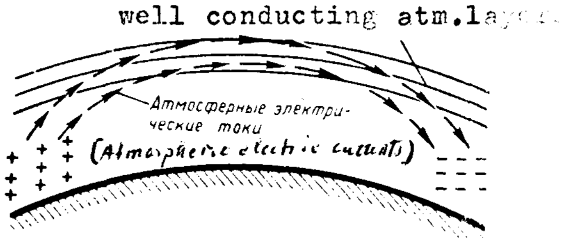


Fig. 3. - Atmospheric currents on a slowly-rotating planet.

The introduction of the assumption that part of the radionoises is induced by the gas discharge does not exclude the assumption of planet's atmosphere heating by the "greenhouse" effect that takes place in the atmospheres of the Earth and Mars, and which must be present to a considerably greater degree in the atmosphere of Venus. However, assuming the presence of the "glowing" gas discharge, it is possible to limit ourselves to "greenhouse" effect commensurate with that on the other planets not connected with the difficult to explain, extremely great thickness of the atmosphere in the infrared. Taking the value $T_{rn} = 600^\circ K$ as the most probable for the radionoise temperature, and assuming the true surface temperature of Venus within the range $T = 340 \div 400^\circ K$, we obtain for the estimate of gas discharge radionoises a value $\Delta T_{gd} = 200 \div 260^\circ K$ . Let us consider the gas discharge energy for these initial data. The radionoise power flux from a unit of area may be determined by the Rayleigh- Jeans integration along the wavelength range

$$F_{rn} = \int_{\lambda_0}^{\infty} 2\pi ckT_{rn} \lambda^{-4} d\lambda = 6{,}44 \cdot 10^{-6} T_{rn} \lambda_0^{-3} \text{ erg} \cdot \text{cm}^{-2} \cdot \text{sec}^{-1} \quad (1)$$

where $F_{rn}$ is the radionoise power flux, $T_{rn}$ is the radionoise temperature, $\lambda$ is the wavelength, k is the Boltzmann constant, c is an electrodynamic constant.

The contribution to the flux $F_{rn}$ from gaw discharge noises may be obtained by substracting the flux of purely thermal noises

$$F_{gd} = F_{rn} - F_T \quad (2)$$

where $F_{gd}$ is the gas discharge radionoise flux, $F_T$ is the power flux of purely thermal radionoises.

The quantity $F_T$ is determined by simple substitution into (1) of the mean temperature of planet's heated surface $T_{♀}$; thus

$$F_{gd} = 6.44 \cdot 10^{-6} \Delta T_{gd} \lambda_0^{-3} \quad (3)$$

The flux of thermal energy from the Sun, absorbed by the planet surface and referred to a unitary area, taking into account the spherical shape of the planet, will be as an average

$$F_{\odot} = \frac{S_{♀}}{4} (1 - A) \quad (4)$$

where $S_{♀}$ is the solar constant at Venus' orbit and A is the albedo. Utilizing (3) and (4), we obtain the effectiveness of Sun's thermal energy transformation into gas discharge radionoises, required for raising the observed radionoise temperature by $\Delta T_{gd}$

$$\eta = \frac{F_{gd}}{F_{\odot}} = \frac{4 \cdot 6{,}44 \cdot 10^{-6} \Delta T_{gd}}{S_{♀} (1 - A) \lambda_0^3}. \quad (5)$$

Substituting $S_{♀} = 2.63 \cdot 10^6$ erg·cm$^{-2}$·sec$^{-1}$, $A = 0.61$, $\lambda_0 = 3$ cm and $T_{gd} = 200 \div 260°$ K, we obtain

$$\eta = (1{,}85 \div 2{,}52) 10^{-10} \simeq 2 \cdot 10^{-10}. \quad (6)$$

In laboratory conditions the "glowing" discharge in a gas is known in the form of a positive luminescence column in fluorescent tubes ([12], p. 19). The theoretical and experimental investigations show that :

– the efficiency of energy transformation of an electric direct current into radionoise energy may be determined if the dimensions of the fluorescent tube, the current voltage, the electric field gradient in positive luminescence and its radionoise temperature are known:

– the power lost for gas heating is inversely proportional to the atomic weight of the gas filling the tube;

– the efficiency improves with the diameter increase of the fluorescent tube;

– the efficiency improves with the decrease of discharge luminance, that is, with the transition from the luminous "glowing" to the "silent" nonglowing discharge, for at that time energy losses are curtailed at the expense of inelastic collisions of electrons with atoms accompanied by luminescence.

The available experimental data (see Add. 1) point to the possibility of obtaining in laboratory fluorescent tubes an efficiency of energy transformation of a directelectric current into radionoises of the order of $\eta_I = 10^{-6}$, and also to the fact that in a large-scale gas discharge on the scale of the entire planet, the efficiency may be still higher; comparing this quantity with the generally required efficiency ($\eta$), we obtain for the efficiency of solar thermal energy transformation into the electric energy of atmospheric currents a value $\eta_{II} = \eta/\eta_I \simeq 2 \cdot 10^{-4}$. As will be shown in Add. 2, such a value $\eta_{II}$ may be quite realistic on a slowly rotating planet.

Therefore, the characteristic of atmosphere over a slowly rotating planet points to the possibility of development in the upper atmosphere, on a global scale, of "silent" and "glowing" discharges, creating in micro and centimeter waves an accretion of the observed radionoise temperature. Inasmuch as the atmosphere circulation of "atmospheric breeze" type and the accompanying atmospheric currents must be strongest in the terminator region, which is the hypothesis of presence of radionoises linked with gas discharge, does not contradict the data obtained on Mariner-2. One of the methods of experimental verification of the above outlined assumption might be a detailed analysis of radiobrightness distribution by the planet's disk, allowing to differentiate reliably the "brightening toward the center" from "brightening toward the terminator".

*** THE END ***

## APPENDIX I.

It is possible to assume on the basis of contemporary data that the upper atmosphere layers of Venus contain a great amount of carbon dioxide. Gas-discharge tubes, filled with carbonic acid at pressure of a few mm. Hg, were successfully applied for lighting in 1893 - 1910 [13]; however, they had the practical shortcoming that the carbon dioxide reacted chemically with the material of electrodes. In connection with this, during the following years only fluorescent tubes with inert gases: neon, argon, helium, xenon were used.

A significant number of experiments are known with regard to energy consumption and radionoises related to tubes with inert gases. For gas-discharge tubes with carbon dioxide such data are absent; however, it is possible, with the aid of some theoretical premises, to estimate the energetic and radionoise characteristics, by basing ourselves on the available experimental data even for a gas discharge in a rarefied carbon dioxide.

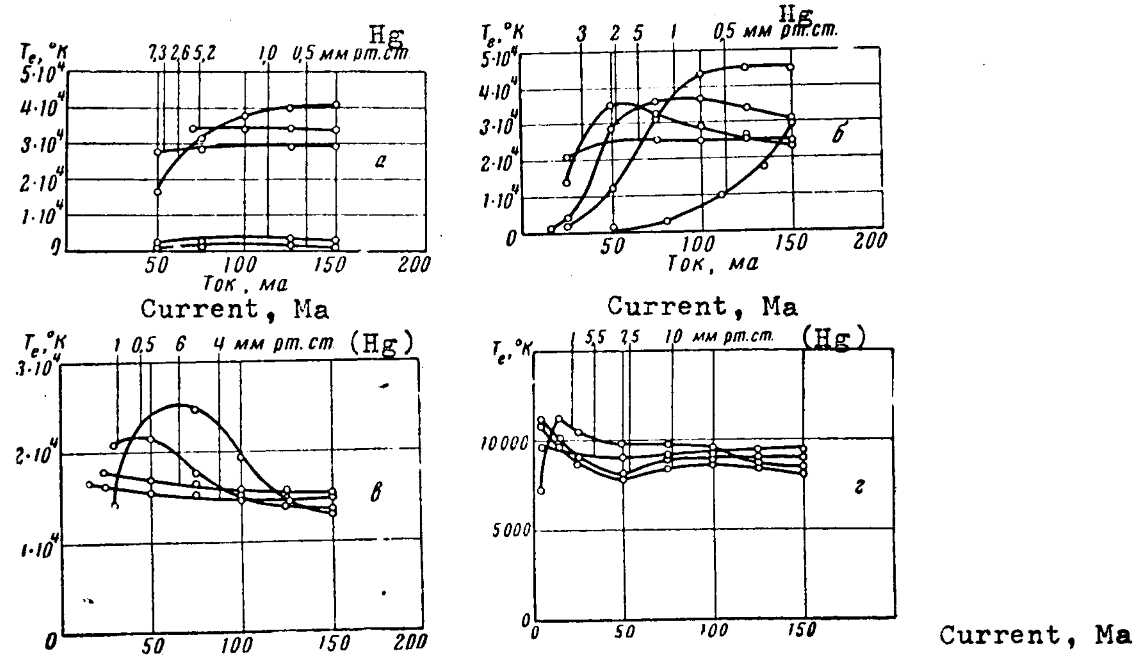


Fig. 4. - Electron temperature $T_e$ of a gas discharge in helium (a), neon (б), argon (в) and xenon (г)

Fig. 4 constitutes a reproduction of graphs for radionoise Temperature $T_e$ dependence on the force of current for fluorescent tubes with helium, neon, argon and xenon, borrowed from the work [14]. It may be seen from these graphs that the radionoise temperature is sustained approximately constant for a broad range of gas pressures and discharge currents (of the order of $1 \div 3 \cdot 10^{4}$ °K) for various gases). As the current decreases below a specific "threshold", the temperature begins to drop sharply. Such a character of dependence is explained by the fact that when the electrons reach an energy sufficient to excite the atoms, the elastic collisions of electron with atoms are to a significant degree substituted by the inelastic ones. This creates an effect of radiotemperature "limitation", while the residual energy of the current is expended on gas luminance in the final resort. It is well known that by decreasing the gas discharge current to values lying within the "threshold" region, one may obtain a discharge with as low a luminance brightness as may be desired.

In Fig. 5 we reproduced the graphs published in the work [13] for the dependence of electrostatic field strength in the gas discharge on the pressure of gas and the dimensions of the tube.

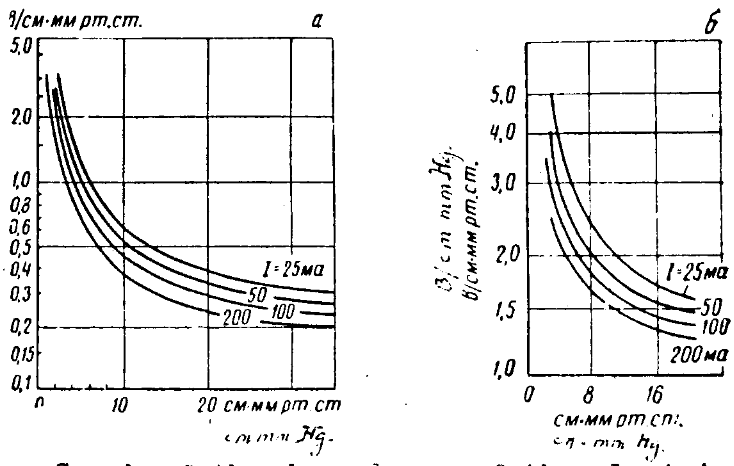


Fig. 5. - Graph of the dependence of the electric field strength on tube dimensions and gas pressure for neon (a) and helium (б) [13].

It may be seen from this graph that :

a) as the atomic weight increases, the strength of the electric field, the other conditions being equal, is approximately inversely proportional to the atomic weight of the gas, and consequently, the same goes for the power consumed in the unit volume of the charge. Thus, according to the graph Fig. 5, 6, for a current of 25 a, 1 mm Hg pressure in a tube of 20 cm diameter for helium (atomic weight 4.003) the field strength is $1.6\ v\cdot cm^{-1}$, and for neon (atomic weight – 20.183) it is $0.4\ v\cdot cm^{-1}$. It is well known [15] that the energy transferred per unit of time by electrons to the gas is for a unitary volume equal to

$$A_{es} = \frac{2}{3} k (T_e - T_g) \frac{2m_e}{m_s} \frac{n_e}{\tau_{es}} \qquad (I,1)$$

where k is the Boltzmann constant, $T_e$ is the electron temperature, $T_g$ is the gas temperature, $n_e$ is the electron concentration, $\tau_{es}$ is the mean time of electron path length, $m_s$ is the mass of gas particle, $m_e$ is the mass of the electron. The above formula corroborates the indicated dependence of energy losses on the atomic weight of the gas;

b) with the increase of tube diameter at given current referred to the unit of tube surface, the power expended by the current feeding the discharge drops also. Thus, for example, according to the graph Fig. 5a, for neon, when the pressure is 1 mm Hg, the diameter is 10 cm and the current is of 25 ma, the strength of the electric field is $0.6\ v\cdot cm^{-1}$, which corresponds to power consumption per $1\ cm^2$ of tube surface

$$N_1 = \frac{0.6 \cdot 0.025}{3.14 \cdot 10} \cdot 10^{-7} = 4.8 \cdot 10^3\ erg\cdot cm^{-2} \cdot s^{-1} \quad (I,2)$$

but for a 20 cm diameter and a current of 50 Ma the strength of the electric field is $0.3\ v\cdot cm^{-2}$, and, consequently the power, referred to $1\ cm^2$ of surface is

$$N_2 = \frac{0.3 \cdot 0.05}{3.14 \cdot 20} \cdot 10^{-7} = 2.4 \cdot 10^3\ erg\cdot cm^{-2} \cdot sec^{-1} \quad (I,3)$$

This dependence is explained by the fact, that as the diameter of the tube increases, the conditions for energy yield from the internal regions of the tube deteriorate on account of conductance as well as of ray emission, and consequently, at given energy losses, the gas must have a higher temperature.

This is why the quantity $(T_e - T_g)$, entering in the formula (I,1), decreases with the increase of tube's diameter (and, generally, with the deterioration of conditions for energy draw-off), which diminishes the energy consumption for sustaining the discharge. This circumstance offers a significant interest for the hypothesis under consideration, inasmuch as the characteristic dimensions of the gas discharge in the upper atmosphere layers have an order of no less than unities of kilometers (in thickness), and consequently, such a discharge must be more economical than the discharges in fluoresecnt tubes of small dimensions (of the order of centimeters or tens of centimeters).

Before considering the energetic and radionoise characteristics of the assumed discharge in rarefied atmosphere layers consisting of carbon dioxide, let us examine the energy balance of a discharge in an inert gas that would be able to induce the required radionoise characteristics of the planet. Utilizing the example (I,3), based upon experimental data, and passing to the inert gas nearest the carbonic gas by particle mass, that is, to argon, and taking into account that, according to the graph (Fig. 4, б) the radionoise temperature of the argon discharge is $T_{Ar} = 16\,000 \div 20\,000^\circ$ K, we obtain :

— the power of the direct current, referred to 1 $cm^2$ of tube surface,

$$N_{Ar} = \frac{m_{He}}{m_{Ar}} = 1.2 \cdot 10^3 \text{ erg cm}^{-2} \cdot \text{sec}^{-1} ; \qquad (I,4)$$

— the porosity of planet surface for its filling by argon discharge required for obtaining $\Delta T_{gd}$

$$q = \frac{S_{Ar}}{S_{♀}} = \frac{\Delta T_{gd}}{T_{Ag}} = 0.01 \div 0.016,$$

where $S_{Ar}$ is the aggregate area of argon gas-discharge radionoise emitters, $S_{♀}$ is the area of Venus'surface).

$N_I$ , the power consumption of the firect current per unit of planet surface is equal to

$$N_I = q N_{Ar} = (12 \div 19) \text{ erg} \cdot \text{cm}^{-2} \cdot \text{sec}^{-1}.$$

The flux of thermal energy from the Sun, corresponding to a unit of Venus' surface (taking into account the albedo and the spherical shape of the planet) is equal to

$$F_{\odot} = 2.5 \cdot 10^5 \text{ erg cm}^{-2} \text{ sec}^{-1}.$$

That is why it is required for the considered example that the efficiency of the transformation of Sun's thermal energy into energy of atmospheric currents feeding the gas discharge be equal to

$$\eta_{II} = \frac{N_I}{F_\odot} \simeq 10^{-4}.$$

On the basis of theoretical considerations one may expect that the transition from the examined, sufficiently artificial example, to a really assumed large-scale gas discharge in the atmosphere, will entail a further lowering of the quantity $N_I$, and consequently, the lowering of the efficiency required for the generation of atmospheric currents, $\eta_{II}$. Indeed, the characteristic dimensions of a discharge in the atmosphere are by many orders greater than the dimensions of fluorescent tubes, for which the values of $N_2$ and $N_{Ar}$ were determined, whereas the walls, removing the heat, are generally absent. The substitution of an argon discharge to a really anticipated model of discharge in carbon dioxide may lead to further improvement of onset and development conditions of a discharge. The presence in carbon dioxide molecule of numerous rotational excitation levels with significantly lower energetic levels than for monoatomic gases, must lead to the fact that the effect of electron temperature "limitation" at the expense of the onset of gas glow must take place at lower electron temperatures, of the order of several hundred or one thousand degrees Kelvin; at the same time the emission must take place at weak currents and low field intensities in the region of long infrared waves first of all. At such a radiotemperature one should expect the engulfing of a greater region by the discharge, that might occupy nearly the entire territory encompassed by the "global breeze", that is, a region of the order of 0.5 — 0.6 of the entire planet surface.

The indicated distribution is more advantageous from the standpoint of energy than the presence of separate "seats" with high radiotemperature, for here the losses linked with energy transfer from practically the whole surface of the planet to the "seats" of radio emission are absent. At the same time, at large-scale discharge the conditions of energy yield by the gas through conductance and radiation will be approximately the same as in the earlier considered models; consequently, the relative difference $(T_e - T_g)/T_e$, and alongside with it the efficiency of current energy transformations into radionoises may have the same order as in the types of discharges considered above.

The above estimates show the complete reality of the development in Venus' atmosphere of "silent" and "glowing" gas discharge at scales, assuring an average of temperature accretion about the disk by $200 - 260^\circ$ K.

Let us examine the approximate parameters of the atmosphere in the zone of gas discharge. Considering the motion of every electron as the sum of rectangular current pulses with durations equal to the run time of the electron between collisions, it is not difficult to establish that the spectral density of elementary currents induced by the motion of electrons, is practically constant (is not dependent on frequency) at $f \ll 1/\tau_{es}$ and it rapidly decreases with the rise of frequency at $f \gg 1/\tau_{es}$ ($\tau_{es}$ being the mean time of electron run). Inasmuch as the emission temperature at the given frequency is proportional to the spectral density of the currents inducing the emission, we may admit for the conventional boundary between the frequency bands of radionoise emission and the usual thermal emission of the gas, the "limit frequency" in the whole

$$f_{lim} \simeq \frac{1}{\tau_{es}} \qquad (I,5)$$

For the quantitative estimate of the characteristics of a gas discharge we may admit the "limit frequency" value $f_{lim} = 10^{10}$ cps, inasmuch as radio observations show a decrease in the intensity of radionoise emission in wavelengths shorter than 3 cm. Assuming for the estimate $T_e = 1000^\circ$ K, and taking into account (4) alongside with the well known formula linking the temperature and the velocity of the particle $\bar{v} = \sqrt{8kT_e/\pi m_e}$, we obtain at $f_{lim} = 10^{10}$ cps the length of the free path $\lambda_e = \bar{v}/f_{lim} \simeq 2 \cdot 10^{-3}$ cm.

In terrestrial conditions, to the value obtained corresponds the pressure

$$P = 5 \cdot 10^{-3} \text{ bar},$$

that is, an altitude of the order of $35 - 40$ km.

We shall estimate the degree of transparence of an ionized layer, utilizing the well known correlations

$$l = \frac{\lambda_0}{2\pi x}, \quad x = \sqrt{-\frac{\varepsilon}{2} + \sqrt{\left(\frac{\varepsilon}{2}\right)^2 + \left(\frac{2\pi\sigma}{\omega}\right)^2}},$$

$$\sigma = \frac{1-\varepsilon}{4\pi} \nu_{ef}, \quad \varepsilon = 1 - \frac{4\pi l^2 n_e}{m_e(\omega^2 + \nu_{ef}^2)}$$

where $l$ is the path over which the amplitude of the wave damps by e times, $\sigma$ is the conductivity in the frequency $\omega$, $\varepsilon$ is the dielectric constant, $\nu_{ef}$ is the effective collision frequency, $n_e$ is the electron concentration, $\lambda_0$ is the oscillation wavelength in vacuum; we assume for simplicity of estimates that the layer is uniform, thereby obtaining the value of the integral concentration $N_0$ ( total number of electrons in a vertical column of 1 $cm^2$ cross section), necessary for the wave to damp by e times in the discharge layer

$$N_0 = n_e d = \frac{c m_e(\omega^2 + \nu_{ef}^2)\sqrt{\varepsilon}}{2\pi l^2 \nu_{ef}} = 18{,}86 \frac{\sqrt{\varepsilon}(\omega^2 + \nu_{ef})}{\nu_{ef}}$$

where d is the thickness of the layer.

Hence, for example, at $\omega = 6 \cdot 10^{10}$, $\nu_{ef} = 10^{10}$, we obtain

$$N_0 = 6.78 \cdot 10^{12}\, cm^{-2}.$$

Assuming the thickness of the discharge layer to be $d = 5 \div 10$ km, we obtain the required electron concentration $n_e = (0.5 \div 1) \cdot 10^7 cm^{-3}$, which is by one order higher than the concentration existing in the terrestrial ionosphere. Taking into account that in the given case an additional ionization source is assumed — the atmospheric current, inducing the "glowing" discharge, such a concentration is quite realistic.

* * *

../.. Follows App.II.

## APPENDIX II

We shall estimate the possible effectiveness of Sun's thermal energy transformation into energy of the current, feeding the gas discharge $\eta_{II}$. We shall express this quantity by the product

$$\eta_{II} = \eta_{sm} \cdot \eta_{mI}$$

$\eta_{sm}$ being the effectiveness of Sun's thermal energy transformation into the mechanical energy of atmospheric flows, $\eta_{mI}$ — the effectiveness of energy transformation of atmospheric flows into the energy of the current, feeding the discharge.

In order to estimate $\eta_{sm}$, we shall take into account that only the meridional circulation performs the work on a rotating planet; it may be viewed as a thermal engine. In this thermal engine updrafts at low latitudes correspond to adiabatic expansion, and the air current descent corresponds to adiabatic compression. The horizontal overflow in the upper atmosphere layers, from equator to poles, is accompanied by cooling and consequently corresponds to the contiguity of the operational hody with the cold reservoir of heat, whereas the reverse air flow in the lower atmosphere layers corresponds to contact with a hot reservoir. Therefore, the schematical diagram of an "ideal" air circulation could be interpreted as a Carnot cycle, consisting of two isotherms and two adaiabats, whereas the diagram of a real process might be a convex curve, closed all-over, and included in a smaller area inside the "ideal" diagram.

Therefore,

$$\eta_{sm} \leq \frac{\overline{\Delta T}}{\bar{T}} ,$$

where T is the mean temperature of the planet and ΔT is the mean variation of the temperature of air masses at their horizontal displacement from equatorial to polar regions and vice-versa.

For a planet turned toward the Sun by one side an analogous reasoning may be repeated, considering the circulation between the subsolar region of the planet and the side opposite to it.

The rapid rotation of the Earth conditions the strong vorticity of the circulation at middle latitudes. The largest vortices, that is, cyclones and anticyclones with horizontal dimensions of the order of tens of planet's radius, induce a very strong friction, owing to which the energy transport is hindered, and there emerges between the polar and equatorial regions temperature differences of the order of $30^{o}$, and, consequently, the upper limit of $\eta_{sm}$ for the Earth is found to be of the order of 0.1. It is possible to approach the estimate of $\eta_{sm}$ on the basis of other considerations also.

The wind velocity is of the order $0.3 \div 1 \cdot 10^{3}$ cm $sec^{-1}$, while the dissipation time of the kinetic energy of air masses is of the order of $(3 \div 10) \cdot 10^{5}$ sec. The mass of air participating in the circulation is $10^{3}$ $g \cdot cm^{-2}$. Thus the dissipation of wind energy is of the order of $10^{3}$ erg$\cdot$ $\cdot cm^{-2} \cdot sec^{-1}$.

Of the same order is also the kinetic energy of the precipitations, inasmuch as $0.5 \cdot 10^{2}$ $\cdot cm^{-2}$ precipitates from a height of the order $3 \cdot 10^{5}$ cm on Earth, as an average.

Thus in order to obtain $\eta_{sm}$, we must subdivide the mechanical energy losses by the mean solar insolation, that is by a quantity of the order of $10^{5}$ erg $cm^{-2}$ $sec^{-1}$ . As a result, we obtain $\eta_{sm} \simeq 10^{-2}$.

Thus, by adopting for the Earth $\eta_{sm}$ of the order of one percent, we shall not commit a considerable error.

The dissipation of kinetic energy on Venus may be much lower than on Earth, for the planet rotates extremely slowly. In this case, the wind velocity must be high, while the temperature differences at various spots of the planet are small, but sufficient for assuring $\eta_{sm} = 0.01$. Besides, one should bear in mind that for nearly laminar flows on a slowly rotating planet the effectiveness $\eta_{sm}$ may be near to its theoretical upper limit $\overline{\Delta T} / \overline{T}$, and consequently, $\overline{\Delta T}$ may be ofthe order of several degrees.

By way of these considerations, one may in particular explain the paradoxial, at first sight, result of Sinton and Strong [16], [17], obtained by them at measurement of Venus' thermal radiation. If the Sinton data are correct there should be on Venus a vertical gradient comparable with the terrestrial temperature gradient, the horizontal gradient being nearly completely absent. The temperature difference between the lit and dark sides of Venus was only of $4^{o}$ according to Sinton.

It is more difficult to estimate $\eta_{mI}$, the efficiency of mechanical energy transformation into electrical energy, inasmuch as this quantity is dependent on the concrete mechanism of electrostatic field formation in air flows. Taking into account that laminar flows and high wind velocities foster the charge separation and the formation of electrostatic fields, and that an electrostatic engine-type mechanism, having a fairly good efficiency, may act in the atmosphere, we may admissibly postulate

$$\eta_{mI} = 10^{-1} \div 10^{-3},$$

amd consequently,

$$\eta_{I} = 10^{-3} \div 10^{-6}.$$

**THE END**

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